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Vol. 95 JULY 19, 1941 No. 2

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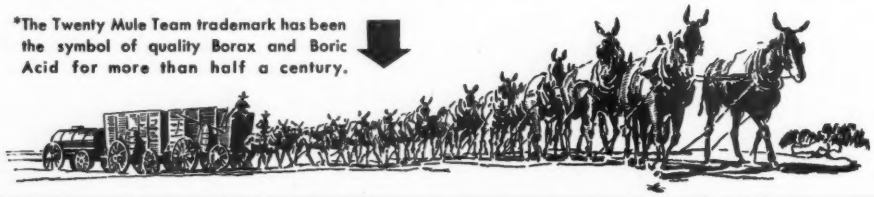

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Vol. 95 JULY 19, 1941 No. 2

Factors Affecting the Caking of Fertilizers*

By J. RICHARD ADAMS and WILLIAM H. ROSS

Fertilizer Research Division, Bureau of Plant Industry, U. S. Department of Agriculture Washington, D.C.

THE materials used in fertilizers represent extremes, in their chemical and physical properties. Fertilizers comprise products that are soluble and insoluble, organic and inorganic, hydrated and anhydrous, pure and impure, fusible and infusible, acidic, basic or neutral, and those that do or do not exhibit a tendency to cake in storage.

When used in fertilizer mixtures, many of these materials react to form new compounds that may differ in their chemical and physical properties from any of the materials used in the mixtures. The extent with which these reactions take place will vary with the initial moisture content of the mixture, the fineness of its particles, the pressure under which it is stored and the temperature and duration of storage. The mechanical properties of a fertilizer mixture, such as its tendency to cake in storage, may be very different therefore for mixtures of the same grade as well as for mixtures of different grades.

Some fertilizer mixtures cake in a relatively short time while others only develop a caked or sticky condition from changes of temperature or moisture encountered after being placed on the market. A laboratory device that would indicate the caking tendency of a fertilizer mixture before being placed on the market should be of interest therefore both to the producer and the consumer of fertilizers.

The present paper describes results obtained in a study of the relative importance of the different factors that determine the caking of fertilizers. The work was undertaken with a view to developing a method for determining in advance the tendency of any material or mixture to cake in storage.

* A paper presented before the Division of Fertilizer Chemistry at the 100th meeting of the American Chemical Society, Detroit, Michigan, September 9 to 13, 1940.

Apparatus

The setting properties of a water-insoluble material, such as plaster of Paris or cement, that passes from a slurry to a solid state on hydration can best be determined by allowing the material to set in a cylindrical mold of known dimensions and then determining the crushing strength of the resulting cake after a definite period of time. Such a test is not suitable, however, for comparing the relative caking tendency of fertilizers while in the solid state. In making a study of the different factors that affect the caking of fertilizers use was made of the apparatus described in a previous publication (1).* With this apparatus it was possible to determine the influence of variations in any given factor on the caking of fertilizers while other factors that affect caking were kept constant.

FIG. 1. Detail drawing of caking bomb.

This apparatus is in the form of a cylindrical bomb, 2 inches in internal diameter. It is

* Figures in parentheses refer to Bibliography at the end of the paper.

readily portable and a total weight of only 2.75 pounds. Means are provided for exerting a constant and known pressure upon the material placed within the bomb. The construction of the bomb is such that it can be readily dismantled for the removal of any cake that may be formed within it. The hardness of the cake formed under the conditions of a test is determined by noting the pressure in pounds per square inch required to break it. Fig. 1

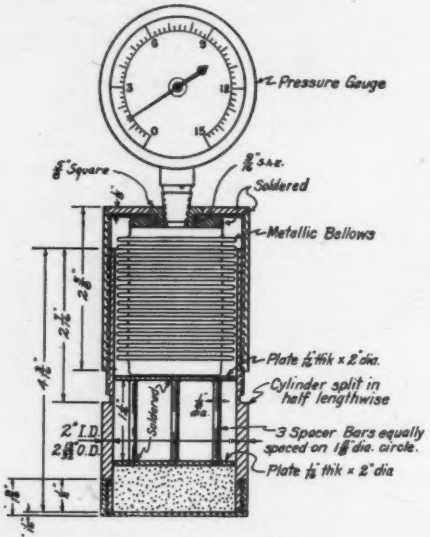

FIG. 2. Bomb assembly.

gives a detailed drawing of the apparatus while Fig. 2 shows an assembled bomb and one partially dismantled with a cake of fertilizer in place.

Variation in Crushing Strength with Thickness of Cake

The relationship found between the thickness of a cake as formed in the bomb and its crushing strength when other factors are the same is shown by the data in Table 1. In making these tests, different quantities of the materials were placed in the bomb under constantly maintained pressure of 12 pounds per square inch and the whole assembly was then stored at 30° C. (86° F.) for 7 days.

The results show that within the range used in the tests the crushing strength of the cakes decreased with increase in thickness until a constant minimum crushing strength was obtained when the ratio of the thickness of the cake to its height had a value that varied with the different materials from about 1.2 to 1.5. These values, which represent the approximate tangents of the angles of shear for the different materials, indicate that for cakes used in crushing strength tests the thickness of the cake should be at least 1.5 times its diameter.

It was found, however, that the caking tendency of different materials falls in the same order whether the thickness of the cake was twice its diameter or the diameter was twice the thickness of the cake. There are several disadvantages in the use of a thick cake in caking tests. A thick cake requires a longer bomb; the time of settling and consequently the time required in making a test is increased; and a cake having a thickness that is greater than its diameter is likely to be less uniform throughout than one in which its thickness is less than its diameter. The cakes formed in subsequent tests were accordingly limited to a thickness of about 1 inch and a diameter of 2 inches.

Variation in Applied Pressure

The variation in the crushing strength of cakes of various air-dried fertilizer materials with the applied or caking pressure is represented by the curves in Fig. 3. The curves show that the crushing strength of the cakes of the different materials increases as the pressure to which they are subjected in their

Table 1

The Relationship Between the Thickness of Briquettes 2 Inches in Diameter and Their Crushing Strength

Temp., 30° C. Particle size, through 80 mesh. Pressure, 12 lb. per sq. in. Caking time, 7 days.

Wt. of Material Grams	Superphosphate		$NH_4H_2PO_4$		$(NH_4)_2SO_4$		$CO(NH_2)_2$		KCl		$NaNO_3$	
	Height of Briquette Inches	Crushing Strength Lb./sq. in.	Height of Briquette Inches	Crushing Strength Lb./sq. in.	Height of Briquette Inches	Crushing Strength Lb./sq. in.	Height of Briquette Inches	Crushing Strength Lb./sq. in.	Height of Briquette Inches	Crushing Strength Lb./sq. in.	Height of Briquette Inches	Crushing Strength Lb./sq. in.
50	7/8	10	1 3/16	204	7/8	409	1 3/16	700	3/4	587	7/8	2,583
75	1 1/4	6	1 1/4	159	1 1/4	226	1 1/2	471	1 5/16	431	1 3/16	1,723
100	1 5/8	5	1 5/8	135	1 3/4	177	2	409	1 1/2	366	1 1/8	1,663
125	2 1/16	4	2 1/8	107	2 1/16	132	2 1/16	286	1 7/8	319	1 7/16	1,204
150	2 3/4	4	2 1/4	42	2 11/16	98	2 15/16	208	2 3/8	236	1 5/8	1,018
175	3 1/16	2	...	...	3 1/8	83	...	...	2 5/8	272	2 1/16	692
200	3 15/16	2	3 3/8	43	3 7/16	99	...	...	3	283	2 1/2	609

Average moisture content: Superphosphate, 1.1%; $NH_4H_2PO_4$, 0.2%; $(NH_4)_2SO_4$, 0.1%; $CO(NH_2)_2$, 0.1%; KCl, 0.9%; $NaNO_3$, 0.1%.

formation increases. This increase in the crushing strength per unit increases in the applied pressure during storage is very marked in the case of certain water-soluble materials such as sodium nitrate and ammonium sulphate but much less marked for other materials such as superphosphate and mono-ammonium phosphate.

The caking pressures used in the tests represented by the curves shown in Fig. 3 ranged up to 15 pounds per square inch. This pressure is equivalent to that developed at the bottom of a pile of fertilizer about 30 feet high and it therefore exceeds that to which fertilizers are normally subjected in commercial practice. In subsequent tests with

Table 2

Effect of Caking Pressures on Hardness of Resulting Cake

Caking Pressure Lb./sq. in.	Crushing Strength $NH_4H_2PO_4$ Lb./sq. in.	Crushing Strength KCl Lb./sq. in.
0	None	None
12	13.4	54.1
48	31.8	...
159	...	628.7
191	133.7	...
318	...	891.3
382	198.9	...
637	330.7	1,661.6

mono-ammonium phosphate and potassium chloride, the applied pressure was increased up to a maximum of 600 pounds per square inch. The data in Table 2 conform to an approximate straight line function between the hardness of the cake and the caking pressures, even up to the maximum used in the tests. The ammonium phosphate used in these tests contained 0.03-0.09% moisture while the potassium chloride contained 0.02-0.09%.

Applied pressures increase the caking tendency of a fertilizer by compacting the particles, thereby increasing their cohesion and causing a closer knitting of the crystals. It should thus be possible to shorten the time required to produce a cake of a given hardness by increasing the pressure to which it is subjected. However, the minimum storage time for a fertilizer mixture in any caking test is determined, as will be shown later, by the reactions taking place in the mixture. Pressures in the neighborhood of 12-15 pounds per square inch seem to be ample to give a satisfactory range in the values found for the relative caking tendencies of different fertilizers. Higher pressures would require a larger and stronger apparatus than that shown in Fig. 1 and 2. The use of pressures in excess of 15 pounds per square inch in any caking test is therefore not recommended unless it is desired to compare different fertilizers that exhibit little difference in caking tendency.

Effect of Particle Size

Under the conditions indicated in Fig. 3 the greatest caking tendency of the materials listed was exhibited by sodium nitrate. A quantity of this material was fractionated by screening into samples of various particle size and each sample was dried to a moisture content of about 0.1 per cent. Tests of the caking tendencies of these fractions showed that fractions coarser than 80 mesh had little or no tendency to cake, while samples of 80-100 mesh or finer

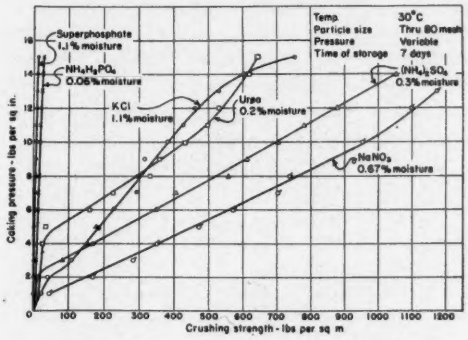

FIG. 3. Variation of crushing strength with caking pressure.

gave measurable caking values and these values increased as the size of the particles decreased.

Fine grinding increases the caking of water-soluble fertilizers by increasing the number of points of contact between the particles. The treatment known as granulation, and particularly one that leads to the formation of spherical granules, decreases the points of contact between the particles and thereby affords one of the most effective means for decreasing the caking of fertilizers.

Effect of Temperature

An increase in temperature increases the solution phase of most soluble fertilizer salts and affects their caking in a manner similar to an increase in the moisture content. A drop in temperature has the effect of causing a crystallization of salts from the solution phase. The effect of temperature on the solubility of potassium nitrate is much greater than for potassium chloride. It might be expected, therefore, that a temperature change would have a greater effect on the caking of potas-

sium nitrate than of potassium chloride. This was found to be true as shown by some preliminary figures given in Table 3. The caking of both materials increased with the temperature but the increase for potassium nitrate was greater than for potassium chloride. The results obtained further show that a four-day storage at 60° C. (140° F.) followed by a three-day storage period at 30° C. (86° F.) produced a harder cake than a continued storage for the same length of time at 60° C.

In this series of experiments, the crushing strength tests were made on the cakes immediately upon removal from storage in order to eliminate, in so far as possible, the effects of any temperature changes. Potassium nitrate and potassium chloride are both stable at relatively high temperatures, and caking tests with these materials may therefore be made at a higher temperature than is practical for mixed fertilizers.

Table 3

Effect of Storage Temperature on Hardness of Resulting Cake

Caking Temperature °C.	Crushing Strength KCl (2.0% moisture) Lb./sq. in.	Crushing Strength KNO_3 (1.8% moisture) Lb./sq. in.
1.7	421.8	334.3
30	1,176.2	1,126.1
60	1,802.5	1,973.6
60 for 4 days followed by 30 for 3 days	1,802.5	2,140.7

Effect of Time of Storage

The effect of the storage period on the caking tendency of a number of fertilizer materials is shown by the curves in Fig. 4. The slope of the curves indicates that the time of storage has a marked effect on the crushing strength of cakes of sodium nitrate but only a relatively small effect on cakes of other materials, such as mono-ammonium phosphate and cured superphosphate. The curve for caked urea shows that a maximum crushing strength is reached after a storage period of about 5 days and for potassium chloride after a storage period somewhat over 7 days. These results and the known rates of curing of different combinations of fertilizer materials make advisable a storage period of 7 days or more in any caking test with fertilizer mixtures.

Effect of Moisture

Slight changes in moisture content have a greater effect on the caking of water-soluble fertilizers than correspondingly small changes in any of the other factors that affect their tendency to cake. The curves in Fig. 5 show that the crushing strength of a cake of sodium nitrate formed under a caking pressure of 12 pounds per square inch for 7 days at 30° C. (86° F.) increased from 200 pounds per square inch at a moisture content of 0.02 per cent to 1,300 pounds per square inch at a moisture content of 0.8 per cent. The corresponding crushing strengths of cakes of potassium chloride were 10 and 475 pounds per square inch as the moisture content was increased from 0.05 to 1.10 per cent.

In addition to the marked effect moisture has on caking, it also imparts a sticky condition to fertilizers and thereby impairs the drillability of materials and mixtures that are insoluble as well as those that are soluble.

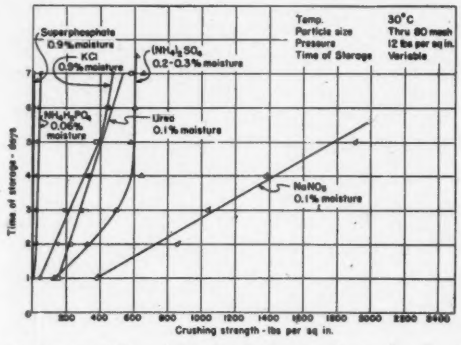

FIG. 4. Variation of crushing strength with the length of the storage period.

Discussion

Finely divided materials may cake as a result of cohesion or adhesion between the particles. Most fertilizer materials, however, are not sufficiently divided to undergo serious caking in this way, although the attraction between particles of a finely-divided material may suffice to interfere with its uniform distribution in the field.

Fertilizers that cake generally do so as a result of a knitting together of the crystals of which the material or mixture is composed. This knitting together of crystals occurs when a material, such as ammonium nitrate, undergoes a change in crystal form, when the crystals flow together under pressure, when a material crystallizes from the solution phase, when new crystals are formed as a result of chemical reaction between the components of a mixture, or when a material combines with the free water present to form a compound containing water of crystallization.

(Continued on page 22)

Tag Sales for June and for Fiscal Year

Fertilizer sales in the 1940-1941 fiscal year, as indicated by the sale of tax tags in 17 States, were 5 per cent larger than in 1939-1940. Aggregate tag sales for the year were 94,000 tons, or 1.5 per cent, below the peak year of 1937. With that exception, 1940-1941 sales were the largest for any year since 1929-1930.

Although commercial sales last year were smaller than in the two earlier peak years, plant food consumption was at an all-time high. This is due to two factors: the steady rise in the plant food ratio and the distribution of fertilizer by Government agencies, neither of which is reflected in the tag sale figures.

Total fertilizer consumption in the United States in 1940-1941, including the tonnage distributed by Government agencies, but excluding phosphate rock sales in Illinois, amounted to approximately 8,700,000 tons.

The increased demand for fertilizer is likely to continue, since farm income is rising substantially and price relationships are favorable to increased fertilizer use.

All of the States reported increases in fiscal year tag sales except Mississippi, where a slight decline occurred. Increases were particularly sharp in Arkansas, Texas, Oklahoma, and the Midwest.

INCREASE IN WAGE SCALE MAY BE CONSIDERED

The fertilizer industry is one of the industries included in a "prospective" list for the appointment, during the fiscal year 1941-42, of "industry committees" to consider raising the minimum hourly wage rate above the 30-cent minimum required generally under the Fair Labor Standards Act. This information was given by Gerard D. Reilly, Solicitor for the Department of Labor, during hearings before a subcommittee of the Committee on Appropriations of the House of Representatives on the Department of Labor Appropriation Bill.

Under the Act, an "industry committee" for any industry is appointed by the Administrator of the Wage and Hour Division, with equal representation of the public, the employers, and the employees. Such an "industry committee," after making investigations, reports its recommendations as to raising the minimum wage for the particular industry involved to the Administrator, who may do one of two things: (1) make an order approving and carrying into effect the recommendations of the committee, or (2) disapprove such recommendations and again refer the matter to the same committee or to another committee for further consideration and recommendations.

FERTILIZER TAX TAG SALES

State	June				July-June			
	1941				1940-41			
	Per Cent 1940	Tons	1940 Tons	1939 Tons	Per Cent 1939-40	Tons	1939-40 Tons	1938-39 Tons
Virginia	100	9,246	9,289	11,252	101	400,047	396,772	418,982
N. Carolina	61	20,176	32,852	24,639	101	1,095,327	1,084,721	1,207,654
S. Carolina	107	17,352	16,250	14,179	105	712,115	678,449	672,753
Georgia	51	7,224	14,210	6,024	108	793,601	736,836	736,179
Florida	102	28,714	28,200	18,581	105	612,230	582,667	547,686
Alabama	84	5,900	7,050	7,010	100	578,050	576,350	552,600
Mississippi	101	9,750	9,675	733	99	342,455	345,010	293,478
Tennessee	81	1,648	2,040	1,170	110	148,387	135,112	133,911
Arkansas	250	750	300	772	117	119,650	102,600	70,822
Louisiana	132	1,780	1,350	1,600	101	171,474	169,673	150,046
Texas	343	1,114	325	205	114	133,354	116,758	92,738
Oklahoma	750	120	16	15	157	10,790	6,872	7,533
Total South	85	103,774	121,557	86,180	104	5,117,480	4,931,820	4,884,382
Indiana	193	35,354	18,300	656	115	345,264	299,213	265,053
Illinois	203	75	37	0	124	62,101	50,079	42,648
Kentucky	48	4,325	9,021	6,975	101	124,799	123,715	111,201
Missouri	100	20	20	2	134	97,701	73,044	66,421
Kansas	...	0	55	0	133	20,786	15,624	15,992
Total Midwest	145	39,774	27,433	7,633	116	650,651	561,675	501,315
Grand Total	96	143,548	148,990	93,813	105	5,768,131	5,493,495	5,385,697

Phosphoric Acid in Soils, and Fertilizing and Liming Problems in Connection Therewith*

By OLLE FRANCK
(*Abstracted by Firman E. Bear*)

(Continued from July 5th issue)

In 1937 a series of field experiments was also carried out to ascertain the effect of the depth into which phosphate fertilizer was dispersed, as well as the fertilizing effect of granulated superphosphate as compared with the conventional commercial pulverized superphosphate. The experimental plan was as follows:

(a) Without phosphoric acid.

(b) 400 pounds of conventional commercial 20% superphosphate per acre harrowed in deeply in spring.

(c) A corresponding amount of phosphoric acid in the form of granulated superphosphate harrowed in deeply in spring.

(d) 400 pounds of conventional commercial 20% superphosphate per acre harrowed in lightly in spring.

(e) A corresponding amount of phosphoric acid in the form of granulated superphosphate harrowed in lightly in spring.

A tabulation of the findings of the grain experiments is given in Table 4. From this table it is seen that the final crop from the soil without any phosphate fertilization averages the lowest in the group whose phosphate condition was the worst according to soil analysis and highest in the group whose phosphate condition was very satisfactory.

The average findings of the two experiments in which the fertilizer was plowed down into the soil with the skim plow are as follows:

	Yield per Acre Lb. of Grain
A. Shallow fertilization without phosphoric acid	2,875
B. Increase in final crop due to 400 pounds of 20 per cent pulverized commercial superphosphate per acre worked down into the soil with the skim plow	360
C. With a corresponding amount of granulated superphosphate worked down into the soil with the skim plow	415
D. With 400 pounds of pulverized commercial 20 per cent superphosphate per acre worked down into the soil with the light harrow	95
E. With a corresponding amount of granulated superphosphate worked down into the soil with the light harrow	135

The granulated superphosphate has therefore given better results in these experiments also than the ordinary commercial type. The superiority of working the fertilizer deeply into the soil is much greater than in the two preceding series. This is only natural when it is borne in mind that the difference between surface penetration and deep harrowing amounts to only an inch, and that even deep harrowing never amounts to more than about two inches. Through skim plowing, however, the fertilizer is brought down into the root layer proper, which is always more or less moist. The phos-

Table 4

Effectiveness of Superphosphate in Relation to Method of Application (Pounds Increase in Yield of Grain per Acre With and Without Phosphate Fertilization)*

Phosphate Condition	Number of Experiments	Total Harvest without Phosphate Fertilization	Deep Harrowing in		Shallow Harrowing in		Average Error for Fertilizing Effect
			Pulverized Superphosphate	Granulated Superphosphate	Pulverized Superphosphate	Granulated Superphosphate	
I. Very unsatisfactory	17	2,700 ± 39	+ 370	+ 440	+ 310	+ 330	± 19
II. Less unsatisfactory	13	3,060 ± 59	+ 110	+ 230	+ 100	+ 150	± 25
III. Satisfactory ..	3	3,400 ± *	+ 20	± 0	— 20	+ 20	....

*"Kilograms per hectare" has been translated "pounds per acre." To be more nearly correct, the figures should be multiplied by 0.9.

phoric acid thus applied is able to exert, even in the first year, a good effect despite insufficient rainfall, and particularly so if the granulated superphosphate, or other suitable fertilizer, is employed in sufficient amounts.

The Interaction of Lime and Phosphoric Acid in Acid Soils

Differences between direct and indirect effects of lime on the soil and on the harvest yield were investigated. Thus, the influence on the harvest yield of lime as an essential plant food is regarded as a direct effect. Soils with a lime content so low as to deserve any special attention in this respect, however, are exceedingly rare, at least as far as farm soils are concerned. The ability of lime to eliminate any excess of hydrogen ions from the soil water is also regarded as a direct effect. It used to be believed that an excess of free hydrogen ions usually exerts an adverse influence on plant growth. More recent researches have shown, however, that the direct damage due to the concentration of hydrogen ions is not a factor that needs to be taken into account, except perhaps in the case of very high acidity with its accompanying deficiency of plant food. Such high concentrations are probably rarely present in the usual farming soils in Sweden.

Certain metals, such as aluminum and iron, when present in the ground water in the ionized form, have an injurious effect on plants. Such injury may be due either to a direct toxic action or to a deficiency in phosphate caused by the fixation of the phosphoric acid. Aluminum seems to be a specific root poison, and is able to precipitate phosphate not only out of the ground water but also out of the root network. In an extremely acid soil plants frequently reveal typical deficiency in phosphate by broken leaves, a strong red-violet coloring at the branch bases. Such phosphate deficiency frequently disappears with liming.

In the years 1932 to 1936, a series of stationary container experiments were carried out for the purpose of studying more thoroughly what influence soluble phosphoric acid has, together with the results to be obtained from phosphoric acid and lime in a type of soil which usually lacks a phosphate supply, that is, a loam. The containers were of the Mitscherlich type. After harvesting, the containers were left standing outdoors through the entire winter in the open field. During long periods of heavy rainfall, however, the containers were covered in such a way as to collect the water. The soil employed in the experiments consisted of an acid (pH value, 5.9), humus-bearing (4 per cent), comparatively phosphate-poor (lactate index, 1.3; Mitscherlich's index* of phosphoric acid, 30), but potash-rich (Mitscherlich's index of potash, 300), slightly sandy loam.

The phosphate fertilizer was provided in the pulverized form, and was at once mixed with the principal fertilizer one week before sowing. The liming was carried out twenty days before spring wheat sowing. The details of the experiment were in accordance with Mitscherlich's general rules for container experiments, except that no sand was added.

In most cases, a considerable influence of both the phosphate fertilization and the lime could be noted soon after the emergency of the plants. The unfertilized and weakly fertilized specimens showed typical phosphate deficiency symptoms, which was not the case with the limed and more strongly fertilized ones. The phosphate effect was very marked. In 1932 the specimen most highly phosphated showed a grain yield of oats of more than double the unfertilized.

The proportion between the stalk yield and the grain yield was considerably changed through the fertilizing. Thus, with the unfertilized specimen one-half more stalk was obtained than grain, while with the most highly phosphated specimen somewhat more grain was obtained than stalk. The ripening process is also accelerated by the phosphate. The unfertilized specimens ripened nearly four weeks later than the most highly phosphated ones.

In the autumn of 1933, after again fertilizing with phosphate, autumn wheat was sowed. In the spring, however, all of the wheat was removed from all the containers with the exception of the most highly phosphated specimens. The whole experimental series was then sowed with spring wheat, but not until after every second container had been limed with 20 grams of lime per container. All of the limed series produced a higher yield than the unlimed. In all of the series the ratio between grain and stalk shifted in such a way that less stalk as compared with grain was obtained through the phosphate fertilization. The thousand-grain weights also increased with increasing phosphate doses both in the limed and in the unlimed series. The ripening time and the phosphate content of the grain was increased through the phosphate fertilization in both series. The lime content of the grain, however, did not show any regular phenomena which

*For phosphoric acid, Mitscherlich's figure of 300 indicates that there is no deficiency in phosphate; the corresponding figure for potash is 200.

(Continued on page 15)

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Principal Articles in This Issue

PAGE

FACTORS AFFECTING THE CAKING OF FERTILIZERS 5

Tag Sales for June and for Fiscal Year... 9

PHOSPHORIC ACID IN SOILS, AND FERTILIZING AND LIMING PROBLEMS IN CONNECTION THEREWITH 10

PROBLEMS CONFRONTING PHOSPHATE PRODUCERS 14

FERTILIZER MATERIALS MARKET:

New York 15
Baltimore 15
Atlanta 17
Wilmington 17
Charleston 18
Chicago 18
Tennessee Phosphate 18

July Cotton Report 12

July Cotton Report

The acreage of cotton in cultivation in the United States on July 1st was estimated by the Crop Reporting Board to be 23,519,000 acres, which is 5.4 per cent less than the 24,871,000 acres in cultivation on July 1, 1940, and 28.6 per cent less than the 10-year (1930-39) average. If the per cent abandoned in 1941 is equal to the 10-year average, an acreage of 23,102,000 is indicated for harvest in 1941. This acreage would be the smallest cotton acreage harvested in any year since 1895. Total plantings are well below the Agricultural Conservation Program allotments, but some farmers whose plantings are in excess of their allotments will undoubtedly remove excess acreage.

Several causes are responsible for this year's reduction in cotton acreage. Frequent and heavy rains in Texas and Oklahoma throughout the spring prevented the planting of some intended acreage and resulted in the loss of some acreage which had already been planted. The Supplementary Cotton Program, in which farmers are given cotton stamps in return for making additional acreage reductions, was also a contributing factor in reducing acreage.

The area in American Egyptian cotton, estimated at 129,300 acres, is almost double the 68,600 acres planted in 1940. The increase in Arizona amounts to 30,000 acres, with the remainder of the increase occurring in New Mexico and Texas. The increases in American Egyptian acreage in Arizona and New Mexico more than balance reductions in short staple cotton in those States. Only a small acreage of this type cotton was planted in New Mexico and Texas last year.

The acreage of long staple Sea Island cotton increased from 30,700 acres in 1940 to 32,300 acres in 1941. In Florida a marked increase in the acreage of Sea Island cotton balances a reduction in short staple acreage. Georgia has about the same Sea Island acreage as last year, but other States show reductions.

V-C APPOINTS SIMPSON TO MONTGOMERY OFFICE

Virginia-Carolina Chemical Corporation has announced the appointment of M. J. Simpson as manager of the Montgomery sales office, succeeding M. E. Hunter who has recently been made Assistant General Sales Manager. Mr. Simpson takes up his duties August 1st.

AAA CONSIDERS 1942 PROGRAM

A conference of AAA State committeemen and other officials has been held to draw up measures for the 1942 AAA farm program. A special practice was recommended by which low-income families may receive seeds, plants, and fertilizers for use in increasing home food production, the cost to be deducted from AAA payments earned by such families. Under this practice, low-income families could also earn additional payments by carrying out live-at-home practices. The conference also adopted resolutions urging the farmer to avoid speculative expansion, to reduce debts, and to build up reserves of cash and farm commodities during the present period of industrial activity of more favorable prices. It also endorsed the price-control work of the Office of Price Administration and urged higher taxes on excess profits, incomes, and luxury items.

TRANSPORTATION COOPERATION ASKED

In a letter to the members of the National Fertilizer Association, Executive Secretary Charles J. Brand has asked for the cooperation of the members of the industry in helping to avoid a possible car shortage later in the season.

"We are becoming more and more concerned," said Mr. Brand, "over the transportation problems that face this country during the present emergency. Our own industry already feels severely the effect of the diversion of ships from the coastwise and intercoastal movement of sulphur, phosphate rock, and potash salts. To move these commodities entirely by rail from producing points to consumption centers will add materially to their delivered costs.

"Commissioner Ralph Budd, in charge of the Transportation Division of the Office of Emergency Management, has asked the cooperation of industry in this emergency, and has requested that all commodities that can possibly be shipped during the summer months be moved as promptly as possible to help relieve the load that will surely come when the movement of farm crops begins this fall. Mr. Budd also issued a number of suggestions for aiding transportation, among which are:

1. Load cars to the limit or to visual capacity.
2. Unload cars promptly on arrival and release them.
3. Give advance notice of car requirements but do not order cars placed until ready to load.
4. Discontinue requests for special switching.
5. Avoid ordering cars in excess of requirements.

"Undoubtedly our industry can most effectively cooperate with the defense agencies and at the same time insure our own requirements as to supplies of fertilizer materials by taking in all needed quantities of raw materials just as quickly as they can be obtained. If transportation priorities are instituted as they may well be, or if priorities on nitrogen or other fertilizer materials are set up, we may not be able to obtain as favorable preferential rating as we did in the World War, and our ability to furnish the farmer his needed supply of plant food may be curtailed."

SUPERPHOSPHATE PRODUCTION INCREASING

In each of the last four months superphosphate production has been larger than in the corresponding month of the previous year, according to reports by acidulators to The National Fertilizer Association. Output during the month was the largest reported for any May in many years. It was 12 per cent above May, 1940, with the entire increase reported by plants in the southern area. Production for the January-May period totaled 1,707,937 tons, compared with 1,598,864 tons during the same months of 1940. Shipments during this period come to 2,849,797 tons in 1941 and 2,491,030 tons in 1940. At the end of May, stocks on hand amounted to 863,633 tons in 1941 and 965,828 tons in 1940.

I. A. C. MOVES GENERAL OFFICE

The International Agricultural Corporation has announced that the removal of its general offices from New York to Chicago, which had previously been reported, will take place on July 21st. The new offices will be located at 20 North Wacker Drive. The general offices of the I. A. C. subsidiary companies, Union Potash & Chemical Company, Phosphate Recovery Corporation and Kyanite Products Corporation, will also be located at the new Chicago address.

On August 4th the portion of the general offices previously maintained at Atlanta will also be removed to Chicago. Sales offices will be continued at 61 Broadway, New York and, for the balance of the summer, at 494 Spring St., Atlanta. Later the Atlanta sales office will be removed to the plant at East Point, Ga.

Problems Confronting Phosphate Producers*

By M. H. McCORD

The Davison Chemical Corporation, Baltimore, Maryland

BACK home the telephone company has recently installed an automatic weather forecasting station. One dials the Weather Bureau, and a pleasant voice gives the forecast for storms or fair weather. These forecasts are based on carefully considered data and are the result of painstaking research and long experience. On the average, they are remarkably accurate. In the short time that has elapsed since Mr. Brand asked me to lead an informal discussion on superphosphate, I have discovered how much more difficult it is to secure factual information with respect to that subject than with respect to the weather.

Any discussion of superphosphate should explore the prospects for production and cover the probabilities of cost.

The superphosphate industry has a rated production capacity of more than 8,000,000 tons of 16 per cent superphosphate, or approximately twice the 1940 production of 4,000,000 tons. Raw material reserves in the form of phosphate rock and sulphur deposits assure an adequate supply for many years. The industry is well equipped to meet any increased production demands of the National emergency.

An inquiry into the probabilities of production cost for the near future is another matter.

The prevailing method of producing superphosphate, as you all know, is by combining phosphate rock and sulphuric acid. Sulphur today is the principal raw material used in the manufacture of sulfuric acid. In the mining of the raw materials as well as in the conversion process, fuel oil and labor are important cost factors. A large percentage of the country's superphosphate plants are operated at points 1,000 miles or more from the phosphate rock and sulphur mines. Transportation of raw materials is a most important element in superphosphate cost.

Our alloted time could be spent in discussing the probable extent of the increase in transportation cost faced by industry during the next several years. It is sufficient to state that we face the certainty of further and substantial increases in the cost of transportation, labor, power, and raw materials.

There are many uncertainties that could be discussed. Timing may delay the sure demand for increased agricultural production. National emergencies and the War can quickly change the direction of our individual lives. They can drastically affect the management and use of the tools employed by the superphosphate industry.

The conditions facing the superphosphate industry in June, 1941, and those that concerned the group of men who attended the National Fertilizer Convention in June, 1917, are primarily similar.

In June, 1917, the agricultural outlook was uncertain, to say the least. The cost of industrial products had increased, farm labor was scarce. Exports of agricultural products had

(Continued on page 20)

* An address before the Annual Convention of the National Fertilizer Association, White Sulphur Springs, W. Va., June 10, 1941.

BRADLEY & BAKER

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FERTILIZER MATERIALS MARKET

NEW YORK

Orders Still Being Placed for Sulphate of Ammonia. Potash Strike Settled but Shortage of this Material Probable. Organic Prices Advance.

Exclusive Correspondence to "The American Fertilizer."

NEW YORK, July 14, 1941.

Many of the buyers of fertilizer materials have not as yet been able to get their full requirements of sulphate of ammonia and are continuing to place orders for this material.

Production at the plant of one of the larger potash manufacturers, which plant has been recently shut down due to strike, has been resumed, but it is doubtful that they have hit their stride as yet and the loss of production due to the duration of the strike is bound to be felt during the new season.

The new seasonal prices on imported nitrate of soda has not as yet been announced.

Organic ammoniates continue firm with additional interest being shown by buyers.

Chesapeake Bay unground menhaden fish scrap continues to be in a strong position. Last confirmed trades on the basis of $4.60 ($5.59 per unit N) and 10 cents, f.o.b. fish factory, in bulk.

Dried blood is likewise firmly held. Last sales on South American material for shipment were accomplished at $3.50 ($4.25½ per unit N).

The market on dry rendered tankage holds quiet but firm, and producers in the New York market are holding at 85 cents per unit of protein, f.o.b. Wet rendered tankage is pretty well sold up in the New York market, with little or no offerings available. Last trades here were at $4.25 ($5.16½ per unit N) and 10 cents.

BALTIMORE

Summer Lull Prevalent. Prices of Organic Ammoniates Advance. Burlap Bag Prices Increased.

Exclusive Correspondence to "The American Fertilizer."

BALTIMORE, July 15, 1941.

The usual summer lull is now on and, in sympathy with the higher market prevailing on feeding materials, the market on organic ammoniates has moved up, but with very little or practically no interest being shown on the part of fertilizer manufacturers.

Ammoniates.—Ground animal tankage for feeding is up sharply to about $4.75 per unit of nitrogen and 10 cents per unit of B.P.L., f.o.b. basis Baltimore. South American ground dried blood for shipment figures about $4.00 per unit of nitrogen, c.i.f. Baltimore.

Nitrogenous Material.—The market on this commodity, in sympathy with the higher ammoniate market, is now about $3.25 per unit of nitrogen, c.i.f. Baltimore.

Sulphate of Ammonia.—There is nothing new to report, but fertilizer manufacturers are taking deliveries against seasonal contracts and stocking up for their future requirements. There are no resale offerings or inquiries on the market, and probably will not be over the balance of this year, as all fertilizer manufacturers will doubtless have more than ample for their requirements until the spring shipping season again opens up.

Nitrate of Soda.—Up to the present time there has not been any change in the market on this commodity and the imported Chilean product is still being sold on the basis of last year's schedule, although higher prices are expected, particularly on bagged nitrate, on account of the materially increased cost of bags.

Fish Scrap.—It is reported that further small sales have been made at the equivalent of about $5.40 per unit of nitrogen and 10 cents per unit of B.P.L., f.o.b. fish factory, for shipment "if and when made" and as produced.

Superphosphate.—The market continues firm on the basis of recently advanced quotations, and none of the manufacturers are pushing the sale, even at present price of $9.50 per ton of 2,000 lb., basis 16 per cent for run-of-pile, and $10.00 for flat 16 per cent grade, no charge for overage, both in bulk, f.o.b. producers' works, Baltimore. Manufacturers are concerned about their supplies of phosphate

FERTILIZER MATERIALS

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SUPERPHOSPHATE

DOUBLE SUPERPHOSPHATE

NITRATE *of* SODA

SULPHURIC ACID

SULPHATE *of* AMMONIA

BONE MEALS

POTASH SALTS

DRIED BLOOD

TANKAGES

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Nashville, Tenn.
New Orleans, La.
New York, N. Y.
Norfolk, Va.
Presque Isle, Me.
San Juan, P. R.
Sandusky, Ohio
Wilmington, N. C.

rock on account of the shortage of vessels available to carry rock to Baltimore.

Bone Meal.—The market on both raw and steamed bone meal continues firm, although the demand is light. 3 and 50 per cent steamed bone meal continues to be quoted at $37.50 to $38.00 per ton, while 4½ and 47 per cent is available around $38.00, f.o.b. Baltimore.

Potash.—The situation on this commodity is also unchanged, and until producers who are now extending their output get their new facilities in operation, they will probably not be in position to take on any additional business.

Bags.—The market on burlap is again considerably higher on account of unsettled European conditions, and figures approximately $216.00 per thousand for plain, new, 10-oz., basis 40 cut 54 in., f.o.b. Baltimore. On this basis there is practically no business passing, particularly for future deliveries, as the price has now gotten so far out of line with the market on paper bags, that manufacturers can hardly afford to use new burlap bags for the shipment of their products.

ATLANTA

Fertilizer Prices Not Advancing as Fast as Other Commodities. Spot Nitrate of Soda Scarce.

Exclusive Correspondence to "The American Fertilizer."

ATLANTA, July 15, 1941.

Fertilizer prices for the most part have shown but little indication of the expected upturn in commodity prices generally. It is becoming increasingly apparent, however, that, with virtually all outside sources of supply except South America cut off, we are in for a steady uptrend in most commodities and this, of course, will have a direct bearing on the various fertilizer components.

Nitrate of soda is still scarce, although the heavy demand for top dressing is about over. Even so, stocks on hand are negligible and a reserve for the coming season will have to be built up.

The markets generally are as follows:

South American Blood.—$3.40 ($4.13½ per unit N), c.i.f.

Tankage.—$3.60 ($4.37½ per unit N) and 10 cents, c.i.f.

Domestic Nitrogenous Tankage.—Nothing presently offered.

Acidulated Fish.—Producers claim to be sold up.

Menhaden Machine Dried Scrap.—$61.00 per ton, f.o.b. South Atlantic fish factories. Meal, $4.00 to $5.00 per ton higher.

Sulphate of Ammonia.—No change from producers current schedule of prices.

Nitrate of Soda.—Unchanged but current spot stocks apparently exhausted.

Cottonseed Meal.—Prime 8 per cent, $30.50, Memphis; southeastern mills, $30.50 to $31.50.

WILMINGTON

Most Buyers Covered in Purchases for Next Season. Possible Shortage of Fish Products.

Exclusive Correspondence to "The American Fertilizer."

WILMINGTON, July 14, 1941.

Trading is very quiet in fertilizer materials. The buyers have about completed their purchases of sulphate of ammonia and superphosphate for the coming season and organics have been largely provided for.

Nitrate of soda is still hard to obtain, but cargoes of Chilean nitrate are expected to begin to arrive next month and will relieve the shortage and supply the demand from then on.

Fishing has been very poor along the South Atlantic coast. All of the factories still have sizeable tonnage to deliver on early contracts and it is difficult to buy any material at this time. The price is nominally $60.00 per ton for scrap and $63.00 for meal.

Manufacturers' Sales Agents for **DOMESTIC**

Sulphate of Ammonia

Ammonia Liquor :: Anhydrous Ammonia

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500 Fifth Avenue, New York

CHARLESTON

End of Potash Strike Welcomed. Organic Materials Bring Higher Prices.

Exclusive Correspondence to "The American Fertilizer."

CHARLESTON, July 14, 1941.

It is reported that the strike at the plant of the American Potash & Chemical Co., has been broken and they have started back into production, but the several weeks' layoff will undoubtedly cause a reduction in their available supply the coming season.

Nitrogenous.—This has advanced quite considerably and is around $2.75 ($3.34½ per unit N), delivered southeastern ports.

Blood.—Around $3.35 ($4.07 per unit N) bagged, c.i.f. ports where freight can be obtained. Around $3.50 ($4.25½ per unit N) bulk, Chicago.

Fish Meal.—Menhaden meal at $65.00 per ton, f.o.b. Baltimore. This continues fairly scarce.

Cottonseed Meal.—Around $32.00 for 8 per cent at Atlanta and $30.75 for 8 per cent at Memphis.

Superphosphate.—The situation on this is getting more and more tight in view of the shortage of sulphuric acid in the Southeast.

CHICAGO

Shortage of Fertilizer and Feed Organics Reported. Sellers Reluctant to Offer Prices for Future Delivery.

Exclusive Correspondence to "The American Fertilizer."

CHICAGO, July 14, 1941.

Trading in organics is more or less in abeyance, principally because of lack of supplies. Buying interest is observed in futures, but sellers are adverse putting out quotations on deferred shipments. They note the advances in other commodities and therefore hold back offerings in the hope of realizing higher values later.

The firm tone in feed materials continues. The finished feed is moving well, and stocks in sellers' hands are light.

Nominal prices are as follows: High-grade ground fertilizer tankage, $3.25 to $3.50 ($3.95 to $4.25½ per unit N) and 10 cents; standard grades crushed feeding tankage, $4.25 to $4.50 ($5.16½ to $5.47 per unit N) and 10 cents; blood, $3.60 to $3.65 ($4.37½ to $4.43½ per unit N); dry rendered tankage, 92 to 97 cents per unit of protein, Chicago basis.

TENNESSEE PHOSPHATE

Drouth Ended for Time Being and Shipments are Expected to Resume Shortly. Hoover & Mason Buys Phosphate Tract.

Exclusive Correspondence to "The American Fertilizer."

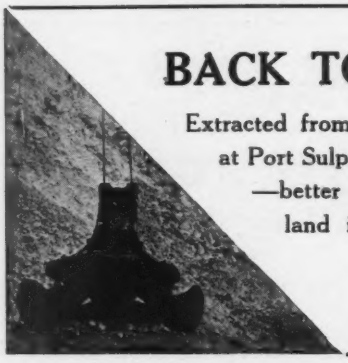
COLUMBIA, TENN., July 14, 1941.

Middle Tennessee's long and costly drouth has at last been ended, for the time at least, by a week or ten days of almost daily rains of magnitude, so that pastures and crops are again green and doing splendidly, barring some wind and hail damage.

Water for washing phosphate is again plentiful for the time and some of the unlucky who did not get their small grain threshed or combined before advent of the rains, begin to feel it will sprout in the shocks.

Shipments of phosphate are in their usual lull but every indication points to heavy resumption of activity in all lines in the next week or two. The AAA continues to increase phosphate consciousness on the part of farmers and, along with the great use of phosphates in the AAA program, sales of material by private industry to those who cannot get in on the free distribution plan, necessarily increase.

It is an expensive way of increasing the use of this absolutely necessary material, but we in



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UNITED STATES POTASH COMPANY, INCORPORATED
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the United States have become used to expensive methods and probably the taxpayers' money will be more advantageously spent in the effort than in some others, though it is hard to see just why the gift of phosphate is necessary, if a small amount of money were spent in distribution of the facts by U. S. Department of Agriculture.

The large tract of land in the Bear Creek area recently mentioned in this letter, under option to the Monsanto Chemical Co., surrounding the Akin property of the TVA, on which they are now building their large mining and washing plant, was not taken up by Monsanto and the option expired. The Hoover & Mason Phosphate Co. have just concluded purchase of this land but terms and prices have not been made public. There is a very large deposit of phosphate of quite good grade on the property which consists of about 1,000 acres and will add to the already large reserves of the Hoover & Mason Co.

PROBLEMS CONFRONTING PHOSPHATE PRODUCERS

(Continued from page 14)

fallen off, there were embarrassing surpluses. The farmer's production cost had risen out of proportion to the increase in the value of his products. There was no prospect of immediate improvement.

The production of superphosphate in 1916 was 3,020,000 tons, basis 16 per cent. During 1916, the cost of labor, power, and transportation had steadily risen. The selling price at Baltimore was approximately 40 cents per unit of available phosphoric acid; it had not been increased during the year. Profits, if any, were measured in pennies per ton.

Between January and June, 1917, there was a further and material increase in manufacturing cost. I find that in April, 1917, individual superphosphate buyers with long-term contracts accepted a price increase of 10 per cent to cover "recent increases in wages."

By June, 1917, new conditions had risen with prospects for rising costs, dwarfing what had gone before. It was rumored that the Government planned to take over all coastwise shipping, and to meet the demands for increased rail wages a czar was to be appointed to adminster the railroads. A shortage had developed in sulphuric acid in the face of increasing Government demands. There was a threat of strikes in the Florida phosphate rock district.

There was scant help to be expected from the Government. Mr. Wilson had just been elected to a second term. In the first term, such new-fangled legislation as the workmen's compensation laws and the income tax had labeled the administration as liberal and unfavorable to business. The epidemic of strikes, even after the declaration of war, had continued unabated, and the newspapers were insistent in their demands that the Government deal with the situation. The Government activities were primarily directed to efforts to equip our new National Army and to increase the production of munitions and ships for our allies. The agricultural problem and the manufacture of superphosphate were distinctly of secondary importance. They could await the settlement of issues of greater moment.

We can be certain that one subject of discussion at the National Fertilizer Association Convention of 1917 was, "Can We Manufacture Superphosphate at a Cost that the Farmer Can Pay?" The answer is, they did—and perhaps in the story of what happened to superphosphate in 1918-1919-1920, there lies the answer to some of the questions that face the industry today.

Every one of their fears of further increases in cost was realized. Within a year the United States Shipping Board took over the operation

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This Durimet Stainless Steel Self-Priming Centrifugal Pump is connected with tank car, acid storage tank and plant service by four lines of acid-proof pipe fitted with four Durimet Y-Valves. In this way, one pump moves acid . . .

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(2) From Tank Car to Plant Service, or
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DURCO
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of all coastwise shipping, and contract rates on phosphate rock from Florida to Baltimore, for instance, were advanced from $1.80 to $4.75 a gross ton. Mr. McAdoo was appointed railroad administrator. All rail rates were increased a flat 25 per cent. There were not enough ships available for the transportation of sulphur and phosphate rock. There were serious car shortages. There were priorities. Wages continued to advance. There were shortages of coal and fuel oil. Beyond their anticipation, there were taxes—from a 3 per cent levy on transportation charges to income taxes at rates which advanced in geometric progression.

The cost of manufacture of a ton of 16 per cent superphosphate nearly doubled between 1916 and 1919. We have some old figures that show in 1916 a cost of $6.41 a ton—$5.35 a ton for materials and $1.08 a ton for conversion cost. The 1919 cost was $10.27 a ton—$8.48 a ton for materials and $1.70 a ton for conversion cost. And in spite of high costs and shortages and priorities, they manufactured superphosphate. The figures show production increases from 3,020,000 tons in 1916 to an all-time high of 5,340,000 tons in 1920.

The other side of the picture belongs to agriculture. This neglected industry of early war days had assumed vital importance by 1918, and the shortages occasioned by the war carried demand for agricultural products to new heights in 1919 and 1920.

Is it reasonable to expect that history will repeat itself and that, with respect to superphosphate, the years 1940 to 1945 will follow the pattern of the years 1916 to 1920? My own conviction is that they will. We face the same basic economic conditions, and similar causes will lead to similar results provided they function in an atmosphere of free enterprise.

Whether or not you share these convictions, a study of the performance of the superphosphate industry 25 years ago under conditions that were surely as difficult as those faced by that industry today creates confidence that it can and will measure up to its responsibilities during the coming difficult years.

FACTORS AFFECTING THE CAKING OF FERTILIZERS

(Continued from page 8)

If the hydrated compound formed in this way is water-insoluble, as in the case of gypsum, normal changes in temperature and pressure have little effect on the ultimate hardness of the caked mass. However, water-soluble hydrates such as monocalcium phosphate, and anhydrous salts that are soluble undergo a partial recrystallization when the temperature of the fertilizer or its moisture content is decreased, or when the applied pressure to which it is subjected is increased sufficiently to cause the crystals to flow together into a more compact mass. In the case of certain soluble materials, such as sodium nitrate, a marked caking may occur with only a relatively slight change in any one or more of these three factors of temperature, pressure and moisture content. It is possible therefore with salts of this kind to hasten the rate of caking by increasing the pressure to which it is subjected. Normal pressures on the other hand have little direct effect on the rate of the reactions that give rise to caking in fertilizer mixtures of the ordinary type (6). Many of the reactions that are known to occur in fertilizer mixtures may require a month or more to go to completion but at 30° C. (86° F.) the greater part of these reactions take place in the course of a week (2, 3, 4, 5, 6, 9). An attempt to hasten a caking test by applying a high pressure over a short period of time to a freshly-prepared fertilizer mixture may thus give a very different result from that obtained on applying a more normal pressure over a sufficiently long time to permit the mixture to approach equilibrium conditions. Any attempt to hasten a caking test by increasing the storage temperature much above 30° C. is also inadvisable because higher temperatures promote reactions that do not occur at lower temperatures (7, 8, 10).

The results obtained in this investigation indicate that the preferred procedure for making a caking test is one in which the sample is stored at 30° C. for 7 days under a con-

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Agricultural authorities have shown that a lack of Boron in the soil can result in deficiency diseases which seriously impair the yield and quality of crops.

When Boron deficiencies are found, follow the recommendations of local County Agents or State Experiment Stations.

Information and references available on request.

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Pioneer Producers of Muriate of Potash in America
See Page 4

tinuously applied pressure of 12 pounds per square inch.

A knowledge of the factors that promote caking in fertilizers should be of help in devising means for reducing the tendency of fertilizers to cake. Applied pressure and the time of storage are more or less beyond the economic control of the manufacturer or of the dealer in fertilizers. It is possible, however, to control other factors that induce caking in fertilizers. Methods are now being developed for retarding chemical reactions in fertilizer mixtures by cooling and drying the mixtures; for reducing the points of contact between the water-soluble components of a fertilizer by granulation and coating of the granules with a water-insoluble material; and for improving the drillability of fertilizer mixtures by so selecting their components that their mutual reaction will reduce rather than enhance their tendency to cake.

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PHOSPHORIC ACID IN SOILS

(Continued from page 11)

can be attributed to the fertilization and liming, except that the average lime content was higher in the limed than in the unlimed series.

The harvest results of the last two years differ very little fundamentally from the preceding years. However, in the last year the effect of even the least increase in the phosphate dose was very considerable in the limed series. The lime content in lucerne dimished with increasing phosphate doses if the increasing phosphate doses were followed by dry farming.

Of the phosphate supplied in the beginning, there remained at the start of the last experimental year in the lactate-soluble form in the

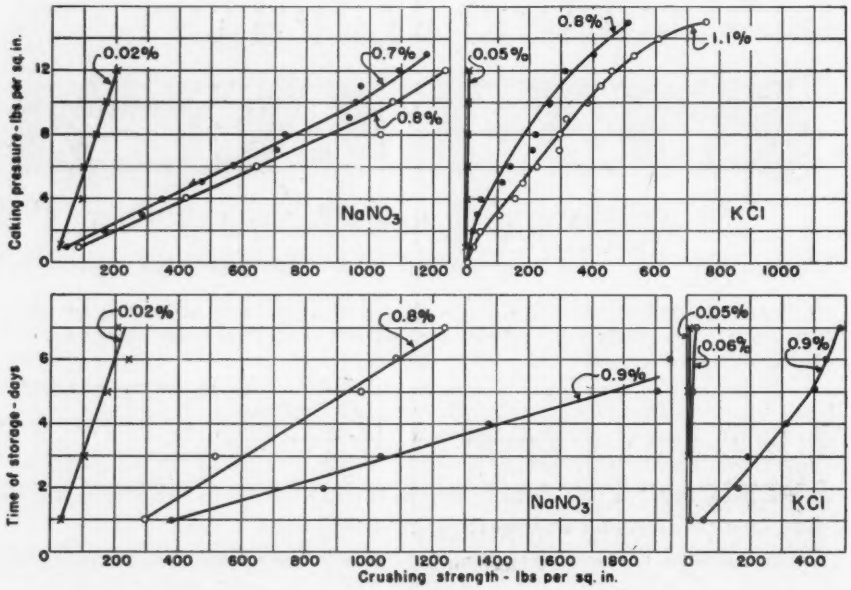
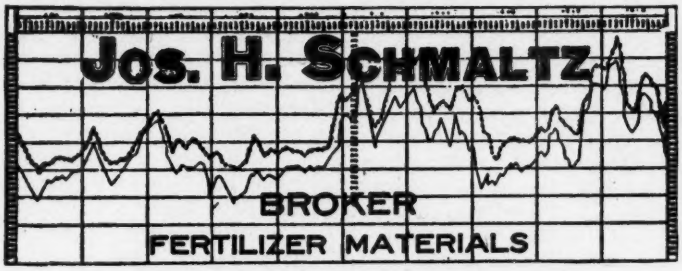


FIG. 5. Effect of moisture on the caking test. Percentages of moisture indicated on each graph.

Tankage
Blood
Bone
All
Ammoniates



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unlimed series 2.5 per cent, 2.5 per cent and 3.3 per cent of the first, second and third phosphate doses, respectively. In the limed series the corresponding values are 12.5 per cent, 12.5 er cent and 25 per cent, respectively. The unfertilized and unlimed soil seems to have attained equilibrium in the spring of 1935 at 40 mg. of lactate-soluble phosphate acid per container, that is, just slightly less than the original value. The phosphate-fertilized and unlimed specimens probably would have reached equilibrium at the same value in a few years. The experimental specimens which were limed but not phosphate-fertilized seem to attain equilibrium at 70 or 80 mg. or lactate-soluble phosphoric acid per container. The lowest phosphate dose would probably attain the same equilibrium in a few years, but the highest phosphate dose would probably require a considerably longer time. A very considerable and very slow (five years at the least) aftereffect is thus indicated for the phosphate-fertilization and liming, and this after effect would probably even continue for a few more years.

Summary

The development of the root system and the appearance of oats and barley were considerably influenced by the method of applying phosphate fertilizer. In the phosphate-fertilized soil layer the roots branched out richly in contrast to what occurred in the unfertilized layer. In the employment of granulated superphosphate in a soil which was very deficient in phosphate, very small and compact root bundles developed around the individual phosphate granules, since the latter constituted comparatively stable phosphate particles from which the plants could easily supply their requirements of phosphoric acid.

Granulated superphosphate showed a greater fertilizing effect than the conventional commercial pulverized product. Moreover, a better fertilizing effect was obtained by working down into the humus layer. Thus, in a soil which was found, according to the lactate method, to be in a very unsatisfactory phosphate condition, there was obtained, when 400 pounds of conventional 20 per cent superphosphate was harrowed in lightly, an average increase in the yield of 310 pounds of grain per acre, as compared with 370 pounds when the fertilizer was harrowed in deeper. For granulated superphosphate, the corresponding values were 330 and 440 pounds, respectively. In soils in a more satisfactory phosphate condition there was obtained, when conventional superphosphate was harrowed in lightly, a yield increase of 100 pounds of grain per acre; with deep harrowing in, 110 pounds; but, when granulated superphosphate was used, 150 to 230 pounds, respectively. In soils which were, according to the lactate method, in a good phosphate condition, no average increase in yield was obtained with either the pulverized or the granulated superphosphate. In soils which were on the dividing line between a very unsatisfactory and a less satisfactory phosphate condition, there was obtained, when 400 pounds of 20 per cent superphosphate was harrowed in lightly, a yield increase of 95 pounds of grain; but of 360 pounds when the fertilizer was worked down with the skim plow. Granulated superphosphate gave yield increases of 135 and 415 pounds per acre, respectively.

In a container experiment which was carried on through a number of years, on a loam which was, according to the lactate method, in a very poor phosphate condition, a very strong, harvest-improving action was obtained from fertilization through at least five successive years. The same effect was obtained with liming. Soil analyses, according to the lactate method, showed that the lime's harvest-improving action may practically be attributed entirely to an indirect phosphate-fertilizing effect. If, therefore, it is a question of improving the phosphate condition of such a soil, liming as well as fertilization must be taken into account.

FARM INCOME RISING

The 1941 farm cash income is now estimated by the Department of Agriculture at about 10.7 billions of dollars. This compares with 9.1 billions in 1940, and with the exception of 1928 and 1929 will be the largest farm income in 21 years. Since prices farmers pay for things they buy are now lower than in other years of large income, farm purchasing power this year is at an all-time peak.

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- - TO A CERTAINTY

the number of pounds of raw material for a desired per cent. of plant food in a ton of mixed goods—or find what per cent. of a certain plant food in a ton of fertilizer produced by a specific quantity of raw materials.

No mathematical calculations are necessary. You can find the figures in a few seconds with the aid of

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How much sulphate of ammonia, containing 20 per cent. of nitrogen, would be needed to give 4½ per cent. nitrogen in the finished product?

Seven hundred and fifty pounds of tankage, containing 8 per cent. phosphoric acid are being used in a mixture. What per cent. of phosphoric acid will this supply in the finished goods?

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This list contains representative concerns in the Commercial Fertilizer Industry, Including fertilizer manufacturers, machinery and equipment manufacturers, dealers in and manufacturers of commercial fertilizer materials and supplies, brokers, chemists, etc.
For Alphabetical List of Advertisers, see page 33.

ACID BRICK
Charlotte Chem. Laboratories, Inc., Charlotte, N. C.
Chemical Construction Corp., New York City.

ACID EGGS
Chemical Construction Corp., New York City.

ACIDULATING UNITS
Chemical Construction Corp., New York City.
Sackett & Sons Co., The A. J., Baltimore, Md.

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American Cyanamid Co., New York City.

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DuPont de Nemours & Co., E. I., Wilmington, Del.
Hydrocarbon Products Co., New York City.

AMMONIA LIQUOR
Barrett Company, The, New York City.
DuPont de Nemours & Co., E. I., Wilmington, Del.
Hydrocarbon Products Co., New York City.

AMMONIA OXIDATION UNITS
Chemical Construction Corp., New York City.

AMMONIATING EQUIPMENT
Sackett & Sons Co., The A. J., Baltimore, Md.

AMMONIUM NITRATE SOLUTIONS
Barrett Company, The, New York City

AUTOMATIC ELEVATOR TAKEUPS
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Bemis Bro. Bag Co., St. Louis, Mo.

BAGS—Cotton
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BAGS—Paper
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BAGS (Waterproof)—Manufacturers
Bemis Bro. Bag Co., St. Louis, Mo.

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Jett, Joseph C., Norfolk, Va.
Taylor, Henry L., Wilmington, N. C.
Wellmann, William E., Baltimore, Md.

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Sackett & Sons Co., The A. J., Baltimore, Md.

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Link-Belt Company, Philadelphia, Chicago.

BEARINGS
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Armour Fertilizer Works, Atlanta, Ga.
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For an Alphabetical List of all the Advertisers, see page 33

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Link-Belt Company, Philadelphia, Chicago.

BURNERS—Sulphur
Chemical Construction Corp., New York City.

BURNERS—Oil
Monarch Mfg. Works, Inc., Philadelphia, Pa.
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CARTS—Fertilizer, Standard and Roller Bearing
Atlanta Utility Works, East Point, Ga.
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Charlotte Chem. Laboratories, Inc., Charlotte, N. C.
Duriron Co., Inc., The, Dayton, Ohio.

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Dickerson Co., The, Philadelphia, Pa.
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Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

GARBAGE TANKAGE
Wellmann, William E., Baltimore, Md.

GEARS—Machine Moulded and Cut
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

GEARS—Silent
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.

GELATINE AND GLUE
American Agricultural Chemical Co., New York City.

GUANO
Baker & Bro., H. J., New York City.

HOISTS—Electric, Floor and Cage Operated, Portable
Hayward Company, The, New York City.
Jeffrey Manufacturing Co., The, Columbus, Ohio.

HOPPERS
Atlanta Utility Works, East Point, Ga.
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

IMPORTERS, EXPORTERS
Armour Fertilizer Works, Atlanta, Ga.
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
Bradley & Baker, New York City.
Wellmann, William E., Baltimore, Md.

IRON SULPHATE
Tennessee Corporation, Atlanta, Ga.

INSECTICIDES
American Agricultural Chemical Co., New York City.

LACING—Belt
Sackett & Sons Co., The A. J., Baltimore, Md.

LIMESTONE
American Agricultural Chemical Co., New York City.
American Limestone Co., Knoxville, Tenn.
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
Bradley & Baker, New York City.
Wellmann, William E., Baltimore, Md.

LOADERS—Car and Wagon, for Fertilizers
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.

MACHINERY—Acid Making
Atlanta Utility Works, East Point, Ga.
Charlotte Chem. Laboratories, Inc., Charlotte, N. C.
Chemical Construction Corp., New York City.
Duriron Co., Inc., The, Dayton, Ohio.
Fairlie, Andrew M., Atlanta, Ga.
Monarch Mfg. Works, Inc., Philadelphia, Pa.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

MACHINERY—Coal and Ash Handling
Hayward Company, The, New York City.
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.

MACHINERY—Elevating and Conveying
Atlanta Utility Works, East Point, Ga.
Hayward Company, The, New York City.
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

A Classified Index to Advertisers in "The American Fertilizer"

BUYERS' GUIDE

For an Alphabetical List of all the Advertisers, see page 33

MACHINERY—Grinding and Pulverizing
Atlanta Utility Works, East Point, Ga.
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

MACHINERY—Power Transmission
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

MACHINERY—Pumping
Atlanta Utility Works, East Point, Ga.
Duriron Co., Inc., The, Dayton, Ohio.

MACHINERY—Tankage and Fish Scrap
Atlanta Utility Works, East Point, Ga.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

MAGNETS
Atlanta Utility Works, East Point, Ga.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

MANGANESE SULPHATE
McIver & Son, Alex. M., Charleston, S. C.
Tennessee Corporation, Atlanta, Ga.

MIXERS
Atlanta Utility Works, East Point, Ga.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

NITRATE OF SODA
American Agricultural Chemical Co., New York City.
Armour Fertilizer Works, Atlanta, Ga.
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
Barrett Company, The, New York City.
Bradley & Baker, New York City.
Chilean Nitrate Sales Corp., New York City.
Huber & Company, New York City.
International Agricultural Corp., New York City.
McIver & Son, Alex. M., Charleston, S. C.
Schmaltz, Jos. H., Chicago, Ill.
Wellmann, William E., Baltimore, Md.

NITRATE OVENS AND APPARATUS
Chemical Construction Corp., New York City.

NITROGEN SOLUTIONS
Barrett Company, The, New York City

NITROGENOUS ORGANIC MATERIAL
American Agricultural Chemical Co., New York City.
Armour Fertilizer Works, Atlanta, Ga.
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
Bradley & Baker, New York City.
DuPont de Nemours & Co., Wilmington, Del.
Huber & Company, New York City.
International Agricultural Corp., New York City.
McIver & Son, Alex. M., Charleston, S. C.
Smith-Rowland Co., Norfolk, Va.
Wellmann, William E., Baltimore, Md.

NOZZLES—Spray
Monarch Mfg. Works, Philadelphia, Pa.

PACKING—For Acid Towers
Charlotte Chem. Laboratories, Inc., Charlotte, N. C.
Chemical Construction Corp., New York City.

PANS AND POTS
Stedman's Foundry and Mach. Works, Aurora, Ind.

PHOSPHATE MINING PLANTS
Chemical Construction Corp., New York City.

PHOSPHATE ROCK
American Agricultural Chemical Co., New York City.
American Cyanamid Co., New York City.
Armour Fertilizer Works, Atlanta, Ga.
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
Bradley & Baker, New York City.
Charleston Mining Co., Inc., Richmond, Va.
Huber & Company, New York City.
International Agricultural Corp., New York City.
Jett, Joseph C., Norfolk, Va.
Phosphate Mining Co., The, New York City.
Ruhm, H. D., Mount Pleasant, Tenn.
Schmaltz, Jos. H., Chicago, Ill.
Southern Phosphate Corp., Baltimore, Md.
Taylor, Henry L., Wilmington, Del.
Wellmann, William E., Baltimore, Md.

PIPE—Acid Resisting
Duriron Co., Inc., The, Dayton, Ohio.

PIPES—Chemical Stoneware
Chemical Construction Corp., New York City.

PIPES—Wooden
Stedman's Foundry and Mach. Works, Aurora, Ind.

PLANT CONSTRUCTION—Fertilizer and Acid
Chemical Construction Corp., New York City.
Fairlie, Andrew M., Atlanta, Ga.
Sackett & Sons Co., The A. J., Baltimore, Md.

POTASH SALTS—Dealers and Brokers
American Agricultural Chemical Co., New York City.
Armour Fertilizer Works, Atlanta, Ga.
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
Bradley & Baker, New York City.
Huber & Company, New York City.
International Agricultural Corp., New York City.
Jett, Joseph C., Norfolk, Va.
Schmaltz, Jos. H., Chicago, Ill.
Taylor, Henry L., Wilmington, Del.
Wellmann, William E., Baltimore, Md.

POTASH SALTS—Manufacturers and Importers
American Potash and Chem. Corp., New York City.
Potash Co. of America, Baltimore, Md.
United States Potash Co., New York City.

PULLEYS AND HANGERS
Atlanta Utility Works, East Point, Ga.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

PUMPS—Acid-Resisting
Charlotte Chem. Laboratories, Inc., Charlotte, N. C.
Duriron Co., Inc., The, Dayton, Ohio.
Monarch Mfg. Works, Inc., Philadelphia, Pa.

PYRITES—Brokers
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., New York City.
Jett, Joseph C., Norfolk, Va.
Wellmann, William E., Baltimore, Md.

QUARTZ
Charlotte Chem. Laboratories, Inc., Charlotte, N. C.

RINGS—Sulphuric Acid Tower
Chemical Construction Corp., New York City.

ROUGH AMMONIATES
Bradley & Baker, New York City.
Schmaltz, Jos. H., Chicago, Ill.
Wellmann, William E., Baltimore, Md.

A Classified Index to Advertisers in "The American Fertilizer"

BUYERS' GUIDE

For an Alphabetical List of all the Advertisers, see page 33

SCALES—Including Automatic Bagging
Atlanta Utility Works, East Point, Ga.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

SCRAPERS—Drag
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Hayward Company, The, New York City.
Link-Belt Company, Philadelphia, Chicago.

SCREENS
Atlanta Utility Works, East Point, Ga.
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

SEPARATORS—Air
Sackett & Sons Co., The A. J., Baltimore, Md.

SEPARATORS—Including Vibrating
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.

SEPARATORS—Magnetic
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

SHAFTING
Atlanta Utility Works, East Point, Ga.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.
Stedman's Foundry and Mach. Works, Aurora, Ind.

SHOVELS—Power
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Link-Belt Speeder Corp., Chicago, Ill., and Cedar Rapids, Iowa.
Sackett & Sons Co., The A. J., Baltimore, Md.

SPRAYS—Acid Chambers
Monarch Mfg. Works, Inc., Philadelphia, Pa.

SPROCKET WHEELS (See Chains and Sprockets)

STACKS
Sackett & Sons Co., The A. J., Baltimore, Md.

SULPHATE OF AMMONIA
American Agricultural Chemical Co., New York City.
Armour Fertilizer Works, Atlanta, Ga.
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
Barrett Company, The, New York City.
Bradley & Baker, New York City.
Huber & Company, New York City.
Hydrocarbon Products Co., New York City.
Jett, Joseph C., Norfolk, Va.
Schmaltz, Jos. H., Chicago, Ill.
Taylor, Henry L., Wilmington, N. C.
Wellmann, William E., Baltimore, Md.

SULPHUR
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
Freeport Sulphur Co., New York City.
Texas Gulf Sulphur Co., New York City.

SULPHURIC ACID
American Agricultural Chemical Co., New York City.
Armour Fertilizer Works, Atlanta, Ga.
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
Bradley & Baker, New York City.
Huber & Company, New York City.
Jett, Joseph C., Norfolk, Va.
Taylor, Henry L., Wilmington, N. C.

SULPHURIC ACID—Continued
U. S. Phosphoric Products Division, Tennessee Corp., Tampa, Fla.
Wellmann, William E., Baltimore, Md.

SUPERPHOSPHATE
American Agricultural Chemical Co., New York City.
Armour Fertilizer Works, Atlanta, Ga.
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
Bradley & Baker, New York City.
Huber & Company, New York City.
International Agricultural Corp., New York City.
Jett, Joseph C., Norfolk, Va.
Schmaltz, Jos. H., Chicago, Ill.
Taylor, Henry L., Wilmington, N. C.
U. S. Phosphoric Products Division, Tennessee Corp., Tampa, Fla.
Wellmann, William E., Baltimore, Md.

SUPERPHOSPHATE—Concentrated
Armour Fertilizer Works, Atlanta, Ga.
International Agricultural Corp., New York City.
Phosphate Mining Co., The, New York City.
U. S. Phosphoric Products Division, Tennessee Corp., Tampa, Fla.

SYPHONS—For Acid
Monarch Mfg. Works, Inc., Philadelphia, Pa.

TALLOW AND GREASE
American Agricultural Chemical Co., New York City.

TANKAGE
American Agricultural Chemical Co., New York City.
Armour Fertilizer Works, Atlanta, Ga.
Ashcraft-Wilkinson Co., Atlanta, Ga.
Baker & Bro., H. J., New York City.
Bradley & Baker, New York City.
International Agricultural Corp., New York City.
Jett, Joseph C., Norfolk, Va.
McIver & Son, Alex. M., Charleston, S. C.
Schmaltz, Jos. H., Chicago, Ill.
Smith-Rowland, Norfolk, Va.
Taylor, Henry L., Wilmington, N. C.
Wellmann, William E., Baltimore, Md.

TANKAGE—Garbage
Huber & Company, New York City.

TANKS
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Sackett & Sons, Co., The A. J., Baltimore, Md.

TILE—Acid-Proof
Charlotte Chem. Laboratories, Inc., Charlotte, N. C.

TOWERS—Acid and Absorption
Chemical Construction Corp., New York City.
Fairlie, Andrew M., Atlanta, Ga.

UNLOADERS—Car and Boat
Hayward Company, The, New York City.
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Link-Belt Company, Philadelphia, Chicago.
Sackett & Sons Co., The A. J., Baltimore, Md.

UREA
DuPont de Nemours & Co., E. I., Wilmington, Del.

UREA-AMMONIA LIQUOR
DuPont de Nemours & Co., E. I., Wilmington, Del.

VALVES—Acid-Resisting
Atlanta Utility Works, East Point, Ga.
Charlotte Chem. Laboratories, Inc., Charlotte, N. C.
Duriron Co., Inc., The, Dayton, Ohio.
Jeffrey Manufacturing Co., The, Columbus, Ohio.
Monarch Mfg. Works, Inc., Philadelphia, Pa.

WHEELBARROW (See Carts)

ZINC SULPHATE
Tennessee Corporation, Atlanta, Ga.

ALPHABETICAL LIST OF ADVERTISERS

For Classified Index, see pages 28 to 32, inclusive

American Agricultural Chemical Co., New York City 3
American Cyanamid Co., New York City..—
American Limestone Co., Knoxville, Tenn..20
American Potash and Chemical Corp., New York City 4, 23
Armour Fertilizer Works, Atlanta, Ga.....16
Ashcraft-Wilkinson Co., Atlanta, Ga., Front cover
Atlanta Utility Works, East Point, Ga. 25

Bagpak, Inc., New York City .....—
Baker & Bro., H. J., New York City, Back cover
Barrett Company, The, New York City ....—
Bemis Bro. Bag Co., St. Louis Mo. .....—
Bradley & Baker, New York City.....14

Charleston Mining Co., Inc., Richmond, Va. 4
Charlotte Chemical Lab., Charlotte, N. C. ..—
Chemical Construction Corp., New York City 21
Chilean Nitrate Sales Corp., New York City.—

Dickerson Co., The, Philadelphia, Pa. .....—
Dougherty, Jr., E., Philadelphia, Pa. 33
Du Pont de Nemours & Co., E. I., Wilmington, Del. .....—
Duriron Co., The, Dayton, Ohio 21

Fairlie, Andrew M., Atlanta, Ga. 29
Farmers Fertilizer Co., Columbus, Ohio 34
Freeport Sulphur Co., New York City....18

Gascoyne & Co., Inc., Baltimore, Md. 34

Hayward Company, The, New York City ..34
Huber Co., L. W., New York City.....25
Hydrocarbon Products Co., New York City.17

International Agricultural Corporation, New York City .....2d cover

Jeffrey Mfg. Co., The, Columbus, Ohio....—
Jett, Joseph C., Norfolk, Va. 34

Keim, Samuel D.. Philadelphia, Pa.....33

Link-Belt Company, Chicago, Ill. .....—

McIver & Son, Alex. M., Charleston, S. C..23
Monarch Mfg. Works, Inc., Philadelphia, Pa. 34

Pacific Coast Borax Co., New York City, 2d cover
Polk Co., R. L., Detroit, Mich. 25
Potash Co. of America, Baltimore, Md., 3d cover

Ruhm, H. D., Columbia, Tenn. 34

Sackett & Sons Co., The, A. J., Baltimore, Md. 26
Schmaltz, Jos. H., Chicago, Ill. 25
Shuey & Company, Inc., Savannah, Ga. 34
Smith-Rowland Co., Norfolk, Va. .....—
Southern Phosphate Corp., Baltimore, Md..—
Stedman's Foundry and Machine Works, Aurora, Ind. 22
Stillwell & Gladding, New York City .....—
Synthetic Nitrogen Products Co., New York City .....—

Taylor, Henry L., Wilmington, N. C. 28
Tennessee Corporation, Atlanta, Ga. .....—
Texas Gulf Sulphur Co., New York City..—

U. S. Phosphoric Products Division, Tennessee Corp., Tampa, Fla. 21
United States Potash Co., New York City..19

Wellmann, William E., Baltimore, Md. 23
Wiley & Company, Inc., Baltimore, Md. 34

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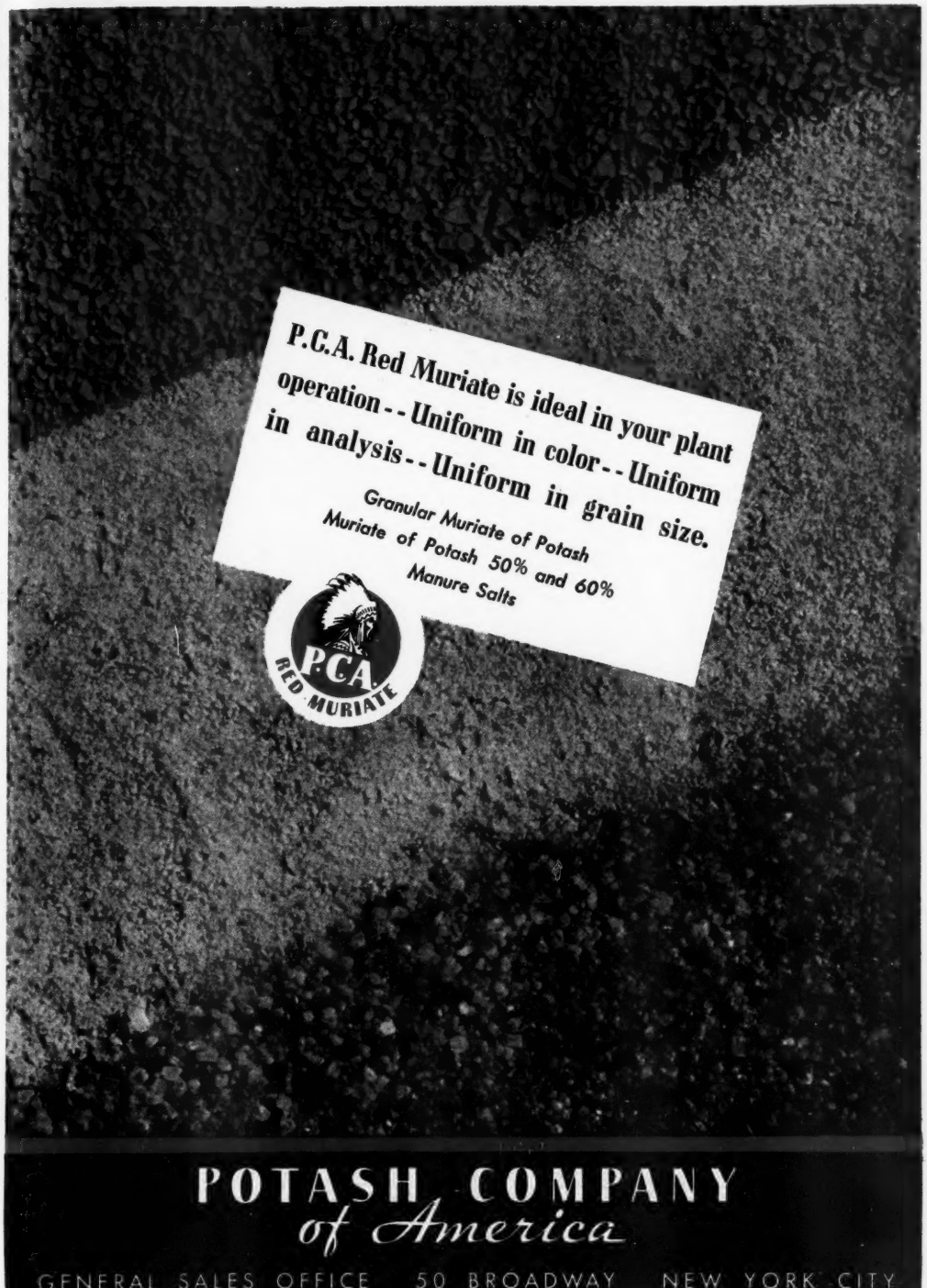
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